Artificially Frozen Ground as a Subsurface Barrier Technology

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Frozen water-saturated ground has great mechanical strength and very low permeability. These properties are exploited by construction ground freezing, a mature civil-engineering practice that has long been used in the North America, Europe and Asia, usually to stabilize the walls of or to restrict groundwater seepage into excavations. Construction ground freezing is often competitive economically with other barrier methods; its principle disadvantage is the long time it can take to form a frozen wall. Recently, artificial ground freezing has been used to form barriers at contaminated sites.The principle advantages of artificial ground freezing for this application, which we designate "environmental ground freezing," are thought to be its ability to form impermeable barriers across transitions from soil to bedrock, a minimal amount of solid material brought to or taken from the site during barrier construction or decommissioning, and great flexibility in designing or adjusting the barrier's size and shape. Some believe that, as a natural process, soil freezing is more likely to find public and regulatory acceptance, though the technique has been implemented at too few contaminated sites to judge this belief.
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In-situ thermal remediation

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Heating has long been used to expedite the cleanup of excavated soils. While there are number of implementations of the concept, they all seek to improve the recovery of contaminants by exploiting the changes in thermophysical properties (e.g., viscosities, interfacial tensions, Gibbs energies of adsorption, and vapor pressures) brought about by increasing temperature. Heating of the subsurface can be achieved by several methods: hot air, hot water, steam, electricity, and electromagnetic radiation. Three general types of contaminants are recovered by these techniques: sorbed organic compounds (e.g., PCB), separate-phase organic liquids with high vapor pressures (e.g., gasoline, chlorinated solvents), and separate-phase organic liquids with low vapor pressures (e.g., crude oil, coal tar, creosote). Steamflooding takes advantage of the fact that water has a high enthalpy of vaporization and that water's boiling point is elevated by hydrostatic pressure by 0.48 °C per meter. Steamflooding to cleanup soils contaminated with low volatility organic materials shows particular promise. If managed properly the technology can improve cleanup by four changes that accompany increasing temperature: (1) increased vapor pressures, (2) increased solubilities, (3) increased rates of bioremediation, and (4) vastly increased rates of abiotic oxidation. Experience with thermal remediation methods indicates that heating with steam is appropriate only for coarse-grained aquifers, which have permeabilities high enough to allow useful amounts of steam to penetrate into the aquifer. Other heating methods (e.g., six-phase heating) are preferred for the in-situ thermal remediation on fine-grained materials. A recent analysis of thermal-method costs considered five scenarios and determined that thermal remediation was cheaper than the best comparable technologies.

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